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The effect of various fiber reinforced composite post surface treatments on its bond strength to root canal dentin

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Abstract

Purpose: Evaluating the effect of various fiber reinforced composite (FRC) post surface treatments on its tensile bond strength to root canal dentin.
Materials and method: Forty extracted human maxillary central incisors were selected. The coronal portion of each tooth was sectioned 15 mm coronally from the root apex. All root canals were instrumented, obturated and the post spaces were prepared to a depth 10mm. The specimens were classified into four groups according to the surface treatment. Group1:- surface treatment with plasma (argon plasma), Group2:- surface treatment with air born- particle abrasion, Group3:- surface treatment with air born -particle abrasion and silane, Group4:- control group without any surface treatment. Two randomly selected posts from each group were examined by Scanning Electron Microscopy (SEM). Self adhesive cement was used for cementation of all posts. Specimens were subjected to thermal cycling for a total of 5,000 cycles between 5 °C and 55 °C, with a 30-second dwell time, 20 sec transfer time at each temperature. The tensile bond strength test was performed using a universal testing machine at a cross-head speed 0.5 mm/min until failure occurred. Posts were examined under stereomicroscope to detect the mode of failure. The data were collected, tabulated and statistically analyzed.
Results: The tensile bond strength of the luting agent to the post was significantly affected by surface treatment ($P < 0.05$). Plasma treated group showed the highest bond strength followed by air-born particle abrasion with silanization and air-born particle abrasion while the control group showed the lowest bond strength.
Conclusion: Both plasma surface treatment and air-born particle abrasion with silane application improved the bonding of fiber post to the resin cement. The effect of plasma treatment was predominant.

Keywords: Fiber post; Surface treatment; Air born abrasive particles; Silane; Plasma; Tensile bond strength

1. Introduction

Endodontically treated teeth may be damaged by decay, excessive wear or previous restorations which resulting in a lack of coronal tooth structure [1]. Posts

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are widely used for retaining the endodontically treated teeth when there is insufficient coronal tooth structure to retain a core for the definitive restoration [2].

Commercially available prefabricated posts were traditionally made of metal alloys, and their use were reported to have less retention, serious types of root fracture, compromised aesthetic, and have the risk of corrosion or allergic reactions [3]. The increasing demand for aesthetic posts has led to the development of metal-free posts, specifically usage of translucent (quartz or glass) fiber posts [4].

Selecting an appropriate adhesive and luting procedure for bonding posts to root dentin is another challenge. Sealing is expected to be strong due to recent improvements in the sealing ability of adhesive resin luting agents [5]. Resin cements increase the retention and tend to leak less than other cements and because of the relatively complicated, technique-sensitive and time consuming disadvantages, some researchers have shifted towards simplified application procedures, which led to the development of self-adhesive resins combining etching and resin infiltration [6].

Failure of restorations using fiber reinforced posts due to dislodgement of the posts occurs most frequently at the post-resin junction [7]. Several surface treatments of the fiber posts have been undertaken to overcome this problem such as mechanical treatment and chemical treatment, which result in surface microroughness, creating a mechanical interlock between the two surfaces, and/or exposure of the fiber by removal of the matrix, permitting silanization with a silane coupling agent (chemical treatment). Some of these treatments may cause detrimental effects on strength of the post when treatment is performed over a long period, such as etching with hydrofluoric acid or blasting with aluminum oxide particles [8].

So it was necessary to evaluate the effect of various FRC post surface treatments on its bond strength to root canal dentin.

2. Materials and methods

Forty single-rooted extracted human maxillary central incisors with fully developed apices, similar size and shape were selected for this study. There width were measured both buccolingually and mesiodistally in millimeters, allowing a maximum deviation of 10% from the determined mean [9]. The specimens were stored in 1%Thymol solution [10].

The coronal portion of each tooth was sectioned 15 mm coronally from the root apex using a diamond double-faced disc, in a slow-speed handpiece, cooled with air/water spray. The roots were embedded in self-curing acrylic resin blocks.

The roots were endodontically instrumented at a working length of 1 mm from the apex using a #40 master apical file.[1] A step-back technique was used with stainless-steel K-files[1] and obturated with gutta-percha cones[1] and resin sealer (AH-26)[1] using a lateral condensation technique. Then the gutta-percha was removed with special preparation drills, leaving a minimum 4—5 mm apical seal and creating a standard post space of 10 mm from the coronal surface corresponding to the conical Easy Post size #4[1] [3].

All posts were equally and randomly divided into four groups (n = 10 per group) according to surface treatment of the post as follows:-

- Group 1: Plasma surface treatment.
- Group 2: Surface treatment with air-born particle abrasion.
- Group 3: Surface treatment with air-born particle abrasion and silane coupling agent.
- Group 4: Control group without any treatment.

2.1. Plasma surface treatment

The posts were surface treated by dielectric barrier discharge (DBD).This plasma system using argon gas at atmospheric pressure. The DBD was generated between two parallel-plate electrodes (25.5 cm × 25.5 cm, gap: 5 mm) driven at a frequency of 50 Hz frequency and a voltage of 20 kV. A limiting resistance R = 250 kΩ is used to limit the discharge current. The cell was fed by gas via gas inlet where the gas fills the gap space and was exhausted through gas outlet; the gas was left to flow in the cell for about 5 min for sweeping any impurities in the gap space before any treatment. The treated posts were fixed at the lower (earthed) electrode where the upper surface of the sample is exposed to the plasma reactive species. For double face treatments, the samples were treated on the opposite side at the same discharge conditions. Samples were exposed to plasma for 6 min[2] [11]

2.2. Airborne-particle abrasion

The posts were surface treated by extra oral sand-blasting device using 50 µm alumina particles at 2 MPa

[1] Dentsply/Maillefer, Ballaigues, Switzerland.
[2] Plasma unit, faculty of science, El Azhar University.

air pressure for 10 s with the posts held perpendicular to the incoming particle stream at 20 mm distance [12]

2.3. Silane coupling agent

After treating the post surface with airborne-abrasive particles a RelyX ceramic primer[3] was applied by the disposable brush on the post surfaces for 60 s and then dried [13].

2.4. Scanning electron microscope (SEM)

Two randomly selected posts from each group were examined by Scanning Electron Microscopy[4] at different magnifications($\times$100, $\times$500).

All posts were marked at a distance of 10 mm and 16 mm from the apical end corresponding to the length of the inserted part of the post space preparation and the exposed part of the post respectively. Then they sectioned horizontally at 16 mm mark with a diamond disc [14].

Dual curing resin cement (RelyX Unicem) [3] was used for cementation of all posts according to manufacturer's instructions.

2.5. Thermal cycling

The specimens were subjected to thermal cycling for a total of 5000 cycles between 5 °C and 55 °C, with a 30-s dwell time at each temperature, 20 s transfer time [15].

2.6. Tensile bond strength testing

For performing tensile bond strength test a specially designed attachment was fabricated and it consists of 2 parts. Tensile bond strength test was performed on a universal testing machine at a cross-head speed of 0.5 mm/min until failure occurred (Fig. 1). Posts after debonding were examined under stereomicroscope[5] to detect the mode of failure. Data were analyzed with one way ANOVA, Post hoc comparison test and Chi-square (X^2) test of significance.

3. Results

The tensile bond strength of the luting agent to the post was significantly affected by surface treatment

Fig. 1. Specimen on universal testing machine.

($P < 0.05$). Plasma treated group showed the highest bond strength followed by air-born particle abrasion with silanization then air-born particle abrasion. While the control group showed the lowest bond strength (Table 1).

Stereomicroscope analysis showed the predominant mode of failure was adhesive in all groups and mixed only in plasma treated group (Table 2).

Scanning electron microscope (SEM) observations: (Figs. 2−5)

4. Discussion

In this study, all tested surface treatment methods produced a better bond strength than control group. This was confirmed by Asmussen et al. [16] and Wang et al. [17] who reported that the surface energy characteristics of dental posts can be modified by using various techniques and influences the bonding of resin −based luting agents.

Table 1
Comparison between the different studied groups as regard the tensile bond strength (MPa) using one way-ANOVA test showing that the tensile bond strength was the highest in plasma surface treated group.

Treatment	Tensile bond strength (MPa)	
	Mean	SD
Plasma	1.31	0.040
Sandblasting	1.23	0.035
Sandblasting + silane	1.27	0.043
Control	1.19	0.037
F	18.203	
P	<0.01[a]	

[a] A highly significance at $P < 0.01$.

[3] 3M ESPE, Seefeld, Ger many.
[4] JEOL-JXA-S40A, USA.
[5] Olympus SZ-CTV, Japan.

Table 2
Comparison between different studied groups as regard mode of failure.

	Mode of failure		
	Adhesive	Cohesive	Mixed
Plasma	2 (20%)	1 (10%)	7 (70%)
Sandblasting	6 (60%)	0 (0%)	4 (40%)
Sandblasting & silane	5 (50%)	1 (10%)	4 (40%)
Control	10 (100%)	0 (0%)	0 (0%)
X2	14.296		
P	0.027[a]		

[a] Significant difference at $P < 0.05$.

The lowest bond strength values were obtained in the control group because the post surfaces are smooth and not altered by any treatment. This result is consistent with previous studies performed by Balbosh and Kern [18] who evaluated the effect of surface treatment on the retention of glass fiber posts and found that non abraded posts had a relatively smooth surface which limited the mechanical interlocking between the post surface and the resin cement and a purely adhesive failure at the resin/cement interface was observed for all non abraded posts.

According to the results of this study, airborne-particle abrasion significantly improved the bond strength between fiber post and resin cement. This finding is consistent with the results of Sahafi et al. [19] as two reasons can be offered for this finding. The air-borne particle abrasion procedure roughened the surface of the fiber post, creating a mechanical interlocking with the resin cement. The increased roughness can also form a larger surface area for bonding.

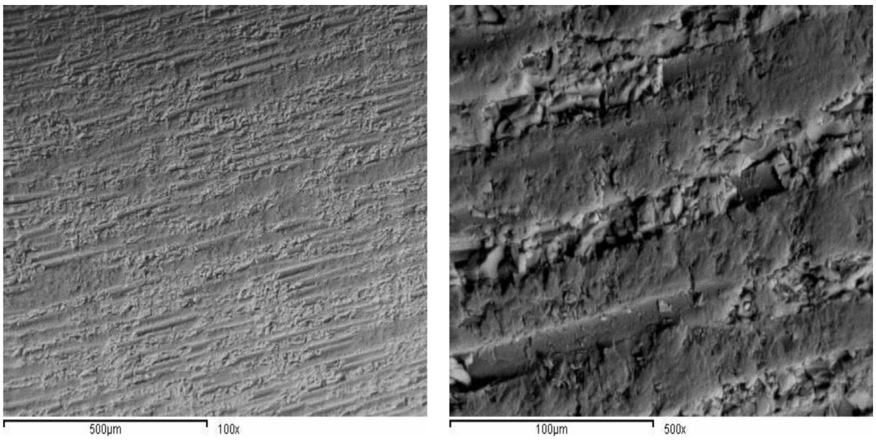

Fig. 2. SEM micrographs with different magnifications (A: ×100, B: ×500) of FRC post in control group. Untreated post surfaces showing solid void free surface and evenly distributed parallel oriented fibers.

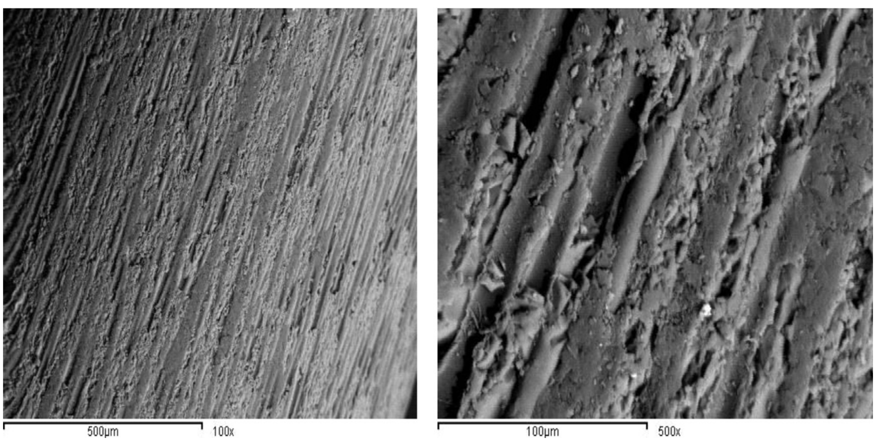

Fig. 3. SEM micrographs with different magnifications (A: ×100, B: ×500) of another FRC post in group 2 (surface treatment with sandblasting) showing the post with a rough surface creating more spaces for micromechanical retention compared to the surface of the control group posts.

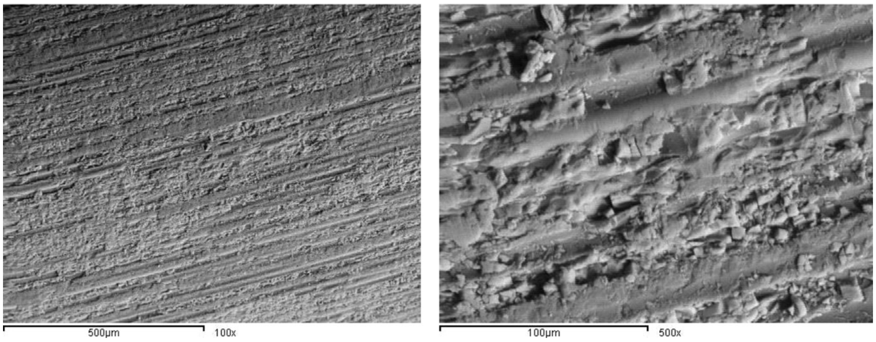

Fig. 4. SEM micrographs with different magnifications (A: ×100, B: ×500) of FRC post in group 3 (surface treatment with sandblasting and silane) showing more interruption of fibers.

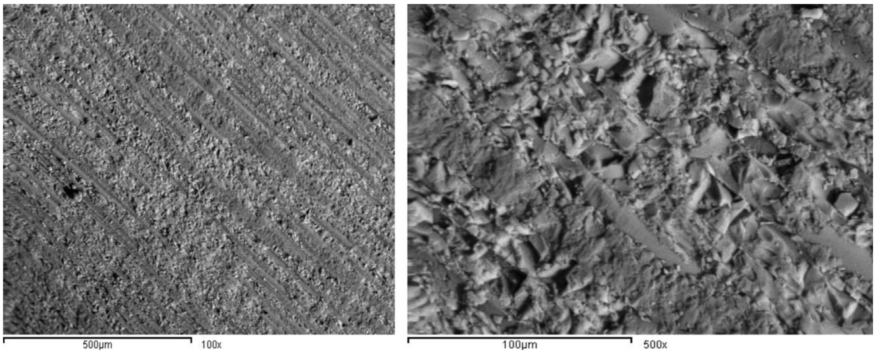

Fig. 5. SEM micrographs with different magnifications (A: ×100, B: ×500) of FRC post in group 1 (surface treatment with plasma) showing more interruption of fibers and increase in surface roughness.

Silanization is a conventional surface conditioning method used in dentistry. However, there are not many studies testing the usage of a silane coupling agent for bonding fiber posts. Some studies found that silane did not increase the bond strength of fiber posts [19,20].

In the present study, the bond strength was enhanced when the posts were airborn-particle abraded and then silanated. This might be explained as sand-blasting leads to roughening of post surface by removing the resin matrix between the silicone fibers making it more retentive in addition to the chemical reaction of silane which relies on the formation of (Si−O−Si) siloxane bonds and conversion of the mineral surface into a less polar surface compatible with organic bonding agent [21,22].

Choi et al. [13] found the highest bond strength was recorded in the air-borne particle abraded group with no additional surface treatment as the highly cross-linked polymers of the matrix in fiber-reinforced posts (DT light post) do not have functional groups for chemical reaction with silane molecules. According to this mechanism, the silane coupling effect to enhance bond strength of the post to resin-based luting agent is increased when fiber-reinforced posts used with more superficial fibers. Following the assumption that no chemical bonding occurred and these finding do not agree with the results of present study due to the difference in the post type used.

The group (1) which was surface treated with argon plasma showed the highest significant results in this study. These results agreed with those obtained by Yavirach et al. [8] who concluded that argon plasma treatment significantly enhanced the tensile-shear bond strength of posts. This might be the result of polymer chain scission caused by the bombardment of energetic Ar particles, which has high molecular-weight particles.

Although inert gas plasma treatments (He−Ar) do not induce any new reactive functionality on the polymer surface, treatment with inert gas can induce free radical formation on the polymer surface through ion bombardment. These free radicals can react with other surface radicals or with other chains in the chain-transfer reactions of polymers. This chemical interaction between free radicals on the surface of the FRC posts and the functional groups luting cement material may occur, thereby resulting in a significant increase in bond strength [23].

It could be assumed that these chemical interactions, as well as, micromechanical interlocking between the two surfaces, were the cause of a higher tensile-bond strength in the FRC posts, because the average surface roughness of the FRC posts was not increased [8].

Dantas et al. [24] found that the samples treated with argon plasma showed the highest hydrophilic characters, presenting lower values of contact angle and the plasma treatments provided a long lasting surface modification which matches the results of our study.

The failure mode may indicate the weak points of bonding to help find an enhancement method in the future. Each failed specimen was examined microscopically at ×15 magnifications in order to classify the mode of failure as adhesive between post and cement, cohesive within post, cohesive within cement and mixed of both types. But the observation of the tested specimens in this study revealed that predominant mode of failure was adhesive in all groups while mixed in plasma treated group only.

These results are in disagreement with Mosharraf and Yazdi [25] who studied the mode of failure in silane treated, airborn —particle abrasion and control groups and found that the predominant mode of failure was cohesive. While it agrees with Wang et al. [26] who found the predominant mode of failure was adhesive in treated posts with silane and sandblasting while control group showed 100% adhesive failure.

While the results of this study showed that the predominant mode of failure in plasma treated group was mixed which agreed with Hongqiang et al. [27] who studied the aging effects of fiber post surface treatment with non thermal plasma and found the predominant mode of failure was mixed type.

Finally, it should be pointed out that all the in-vitro studies have limitations and cannot completely replace clinical trials.

5. Conclusions

Within the limitations of this in-vitro study, it was concluded that:-

1 The tensile bond strength was affected by the surface treatments applied to the fiber reinforced post surface.
2 Plasma surface treatment significantly influenced the tensile bond strength between the FRC posts and root canal dentin more than airborne particle abrasion and silane surface treatments.

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